Multi-Band Template Analysis for inspiraling binaries

Benoit Mours
Caltech & LAPP-Annecy

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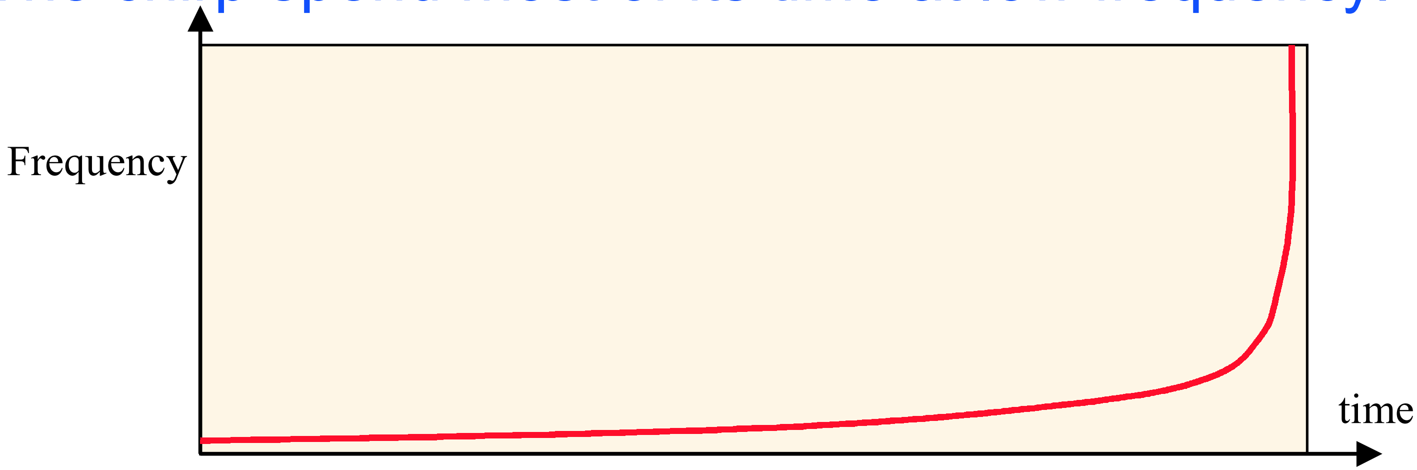
Inspiral search

- Binary search requires large computing resources, especially :
  - » for low mass
  - » if we start at low frequency
- The chirp spend most of its time at low frequency.



  - » The number of templates depends of the chirp length and the maximum chirp frequency
- How to reduce the computing cost?

The Multi Band Template Analysis

- Principle: Split the analysis in a few frequency bands
  - » Equivalent to transform a single detector to a network of detectors.

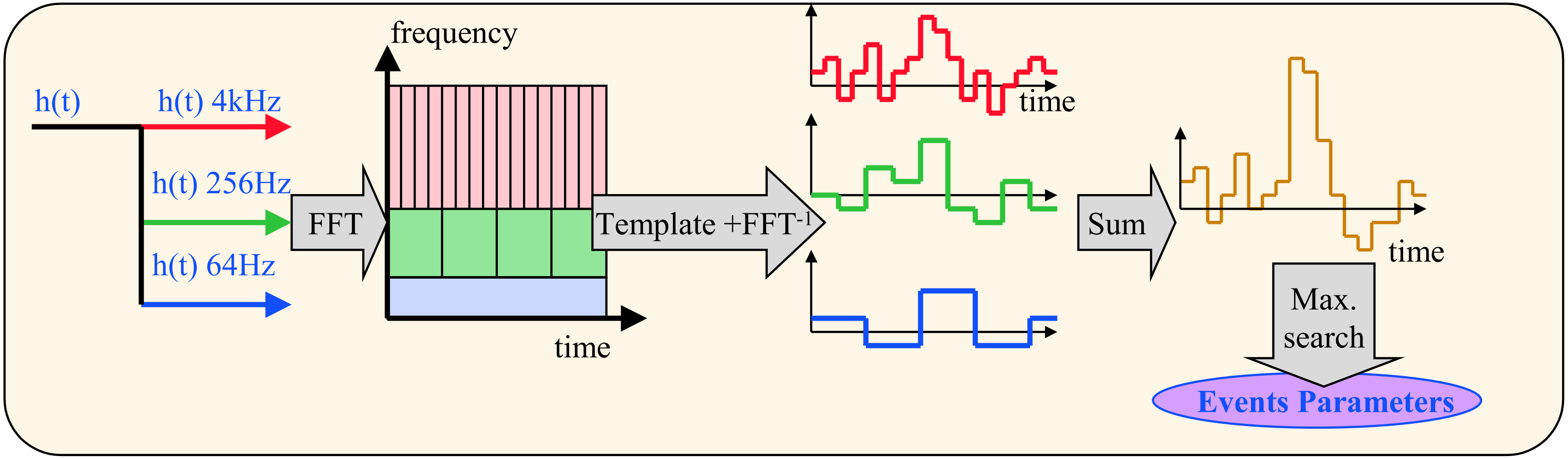
$$LLR(t,M) = \int_{f\,\min}^{f\,\max} h(f)T(M,f)df = \int_{f\,\min}^{f1} h(f)T(M,f)df + \int_{f1}^{f\,\max} h(f)T(M,f)df$$

  - » Analyze independently each band
  - » Combine coherently the analysis result like for a network of detectors

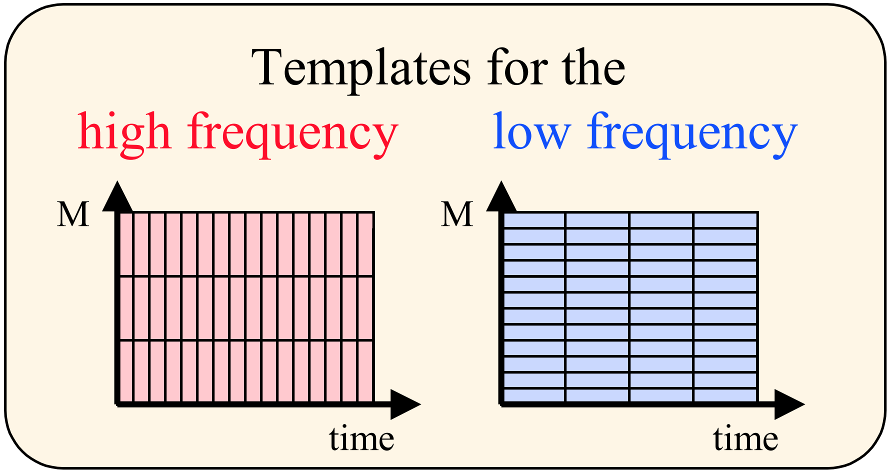
- Each analysis is cheaper because
  - » The number of templates is reduce
  - » The FFT are shorter

- Remarks:
  - » The SNR should be unchanged.

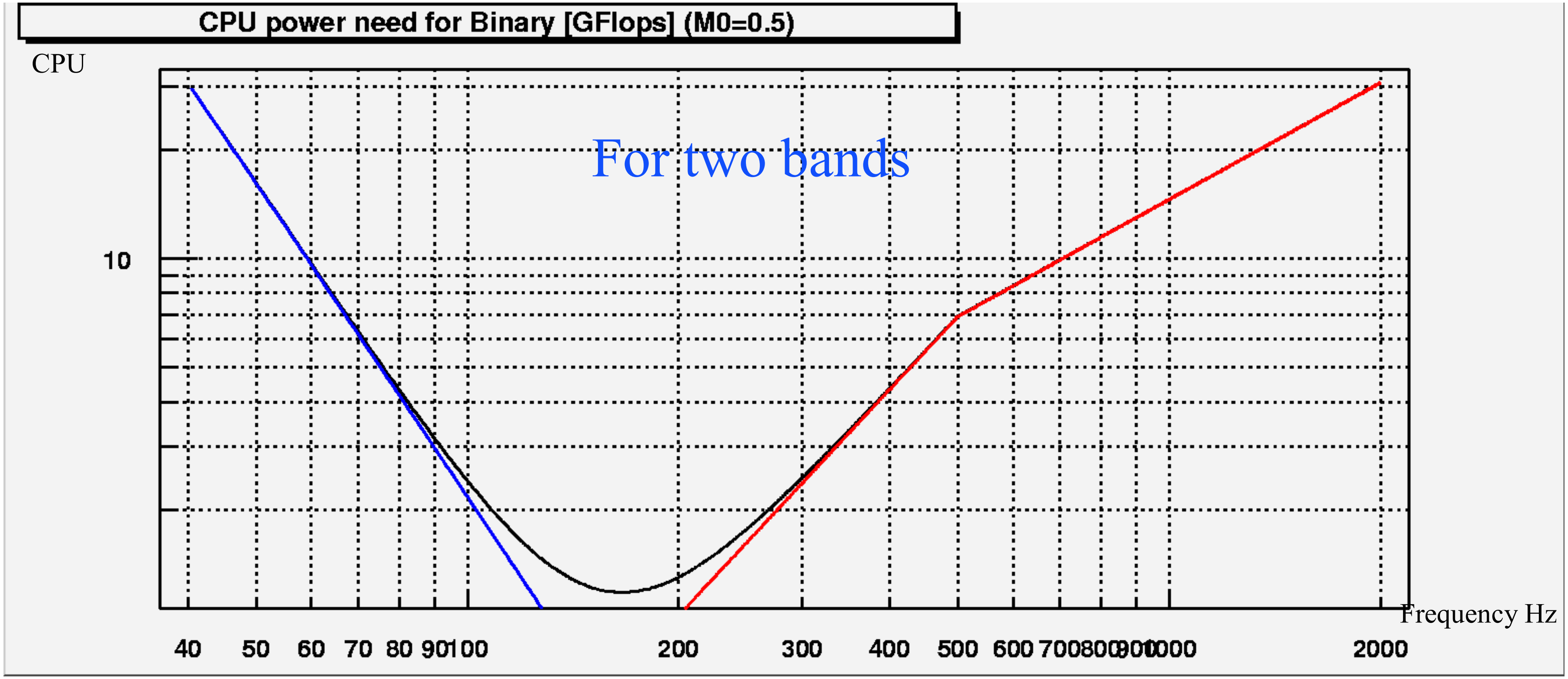
The Multi Band Template Analysis



- Remarks:
  - » All sub analysis cover the same parameter space ***BUT*** may have different grids.
  - » Need interpolation to combine the results and search for the maximum.
  - » All FFT are small FFT.



Estimation of CPU resources



$CPU = K f_{min}^{-8/3} f_s \log_2(f_{min} f_{max})$ (simplify model: $N_{template}$.FFT cost)

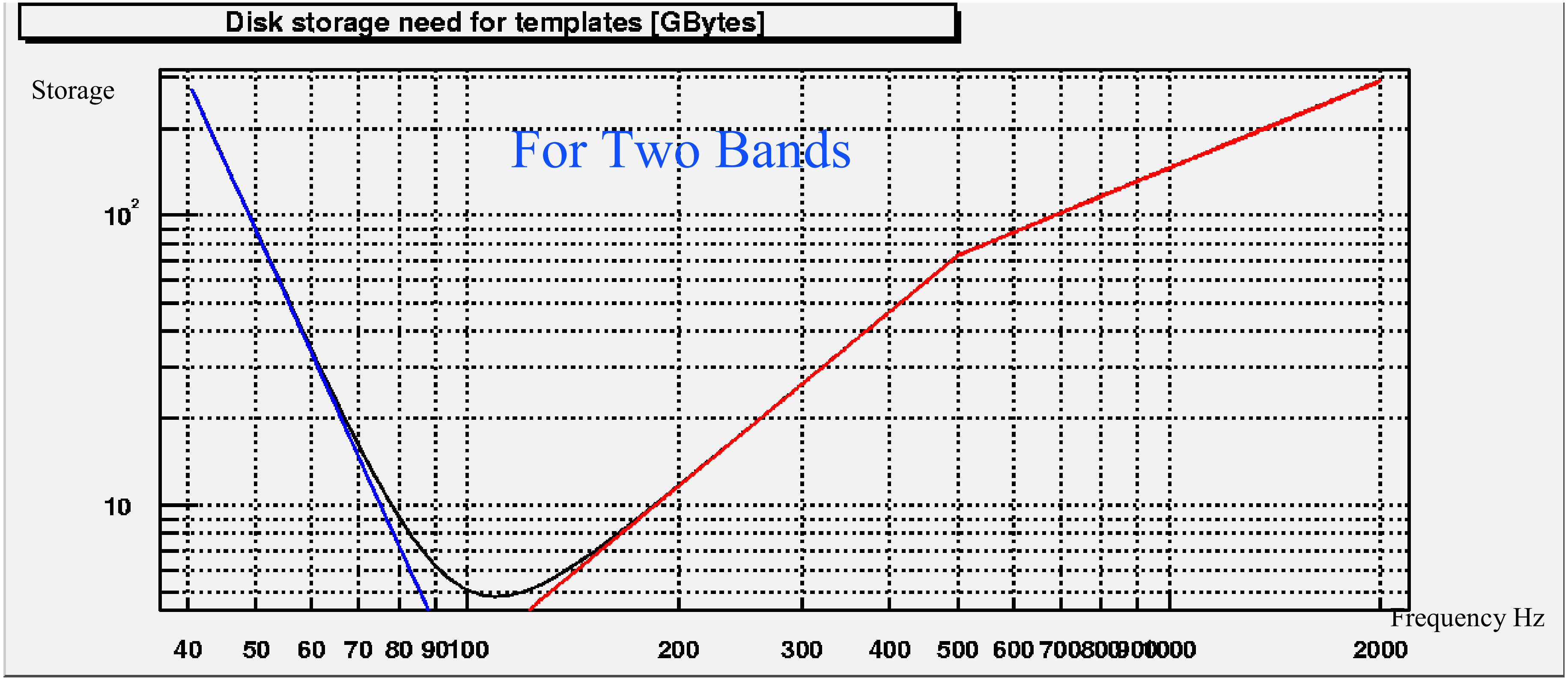
T = Template length (seconds). $= T_0 f_{min}^{-8/3}$

$N_{template}$= T/template spacing

$N_{sample} = 2T f_{max}$

$CPU = N_{template} 6N_{sample} \log_2(N_{sample})/T = K f_{min}^{-8/3} f_{max} \log_2(f_{min} f_{max})$

Estimation Template Storage



$\text{Storage} = K\, f_{min}^{-16/3}\, f_s \log_2(f_{min}\ f_{max}\ )$ (simplify model: $N_{template}$.tempSize)

T = Template length (seconds). = $T_0 f_{min}^{-8/3}$

$N_{template}$= T/template spacing

N_{sample}= 2T f_{max}

$\text{Storage} = 2\ N_{template} N_{sample} = K\, f_{min}^{-16/3}\, f_{max} \log_2(f_{min}\ f_{max}\ )$

LIGO Estimation of computing resources

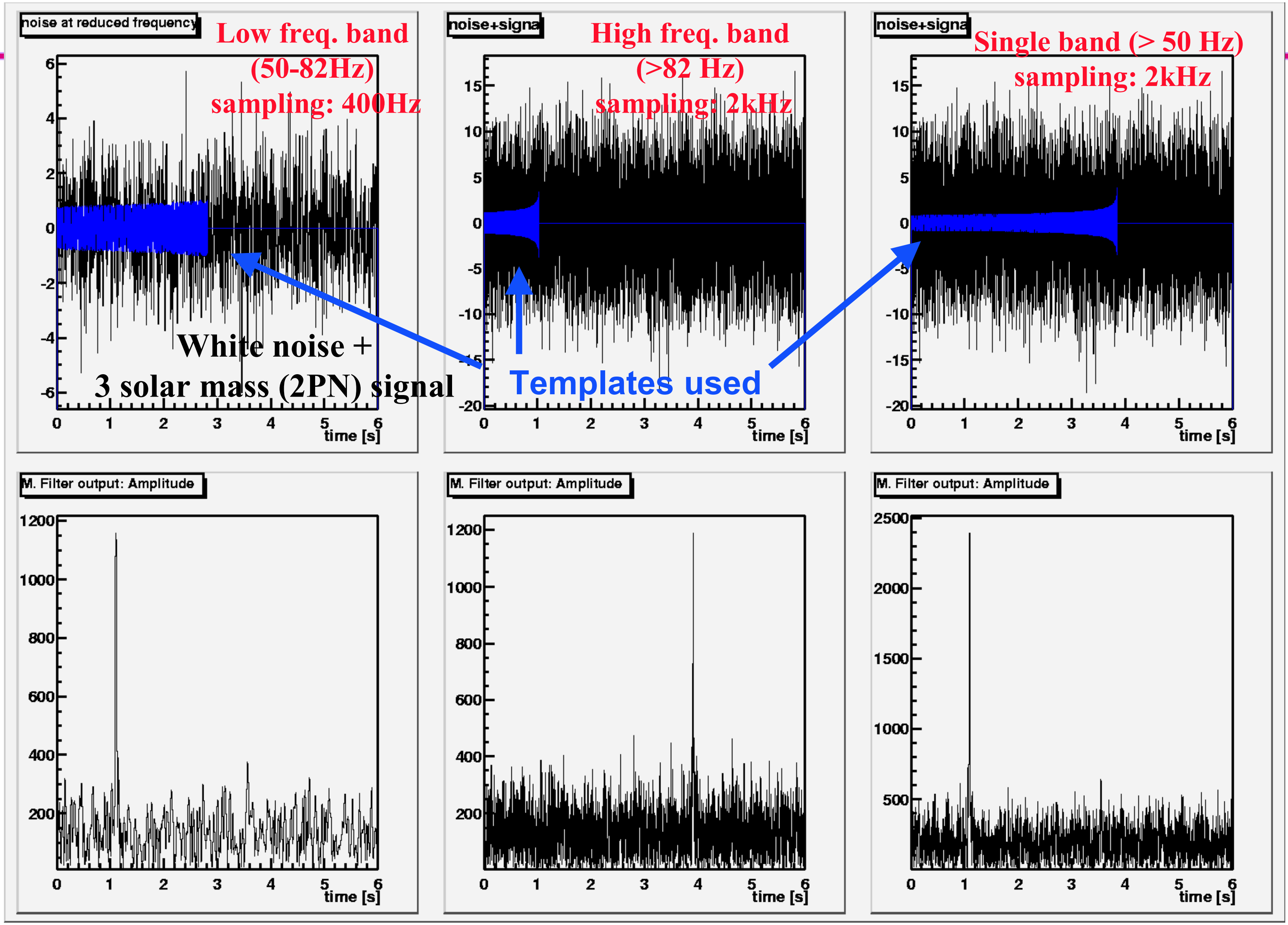
- If f_{min} = 40 Hz, f_{max} = 2kHz, M_{min} = 0.5M

	1 Band	2 Bands	3 Bands
CPU(Gflops)	30	1.3	0.6
Storage (Gbytes)	300	5	2.4
T. size (Mbytes)	2	0.13	0.04

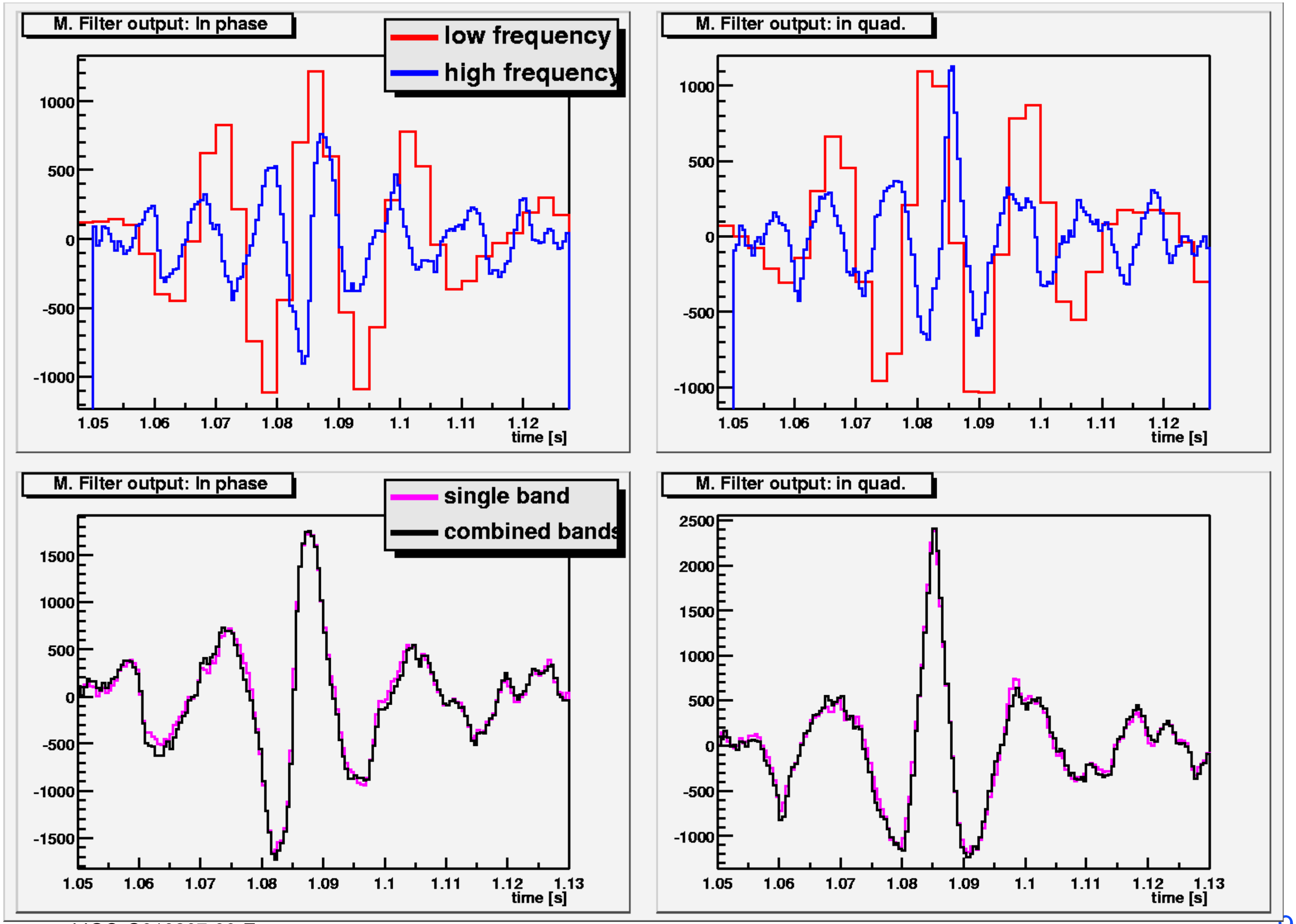
- If f_{min} = 20 Hz, f_{max} = 2kHz, M_{min} = 0.5M

	1 Band	2 Bands	3 Bands
CPU(Gflops)	200	4.3	1.3
Storage (Gbytes)	10000	100	43
T. size (Mbytes)	11	0.6	0.2

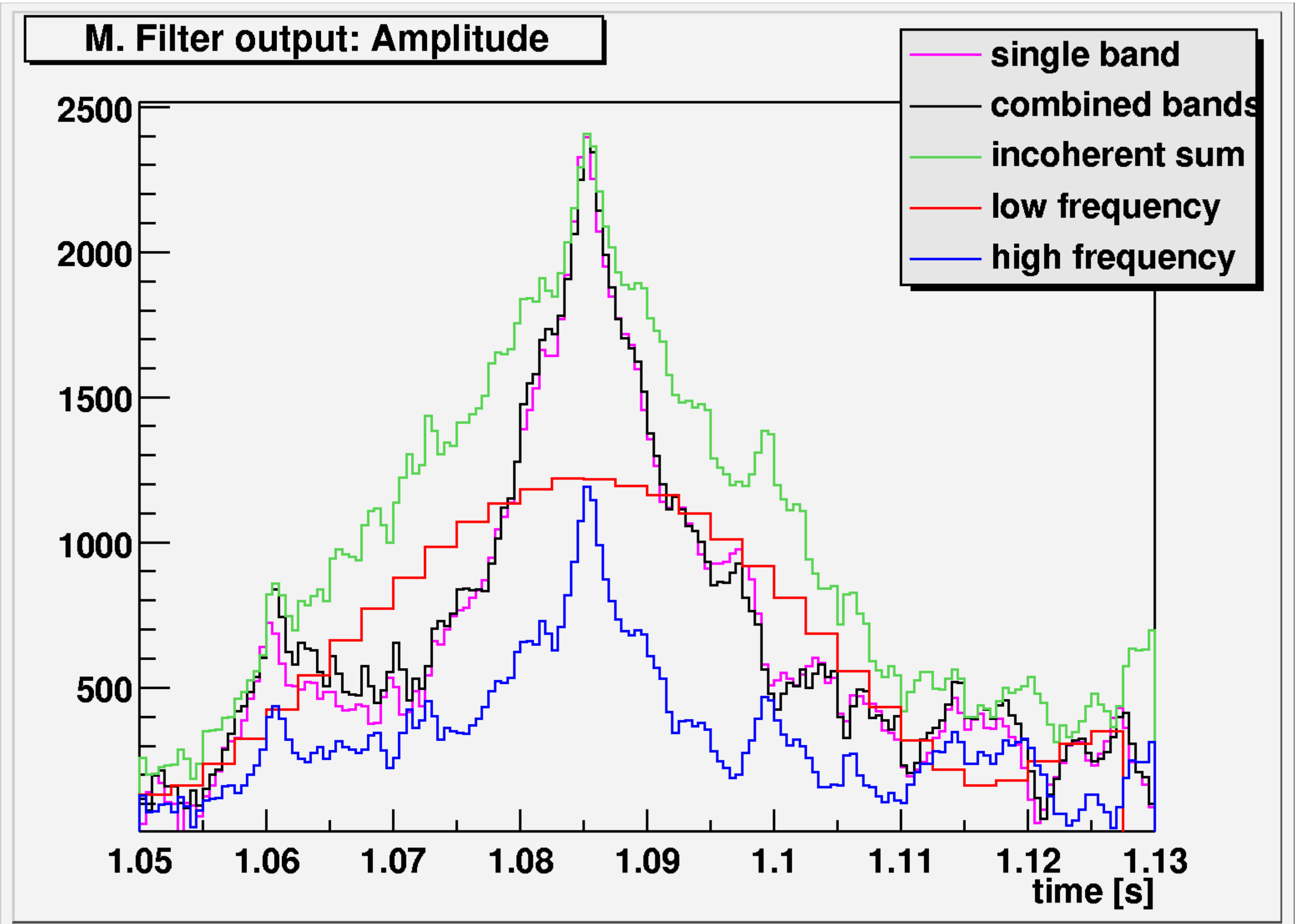
Does it works? Test with 2 bands



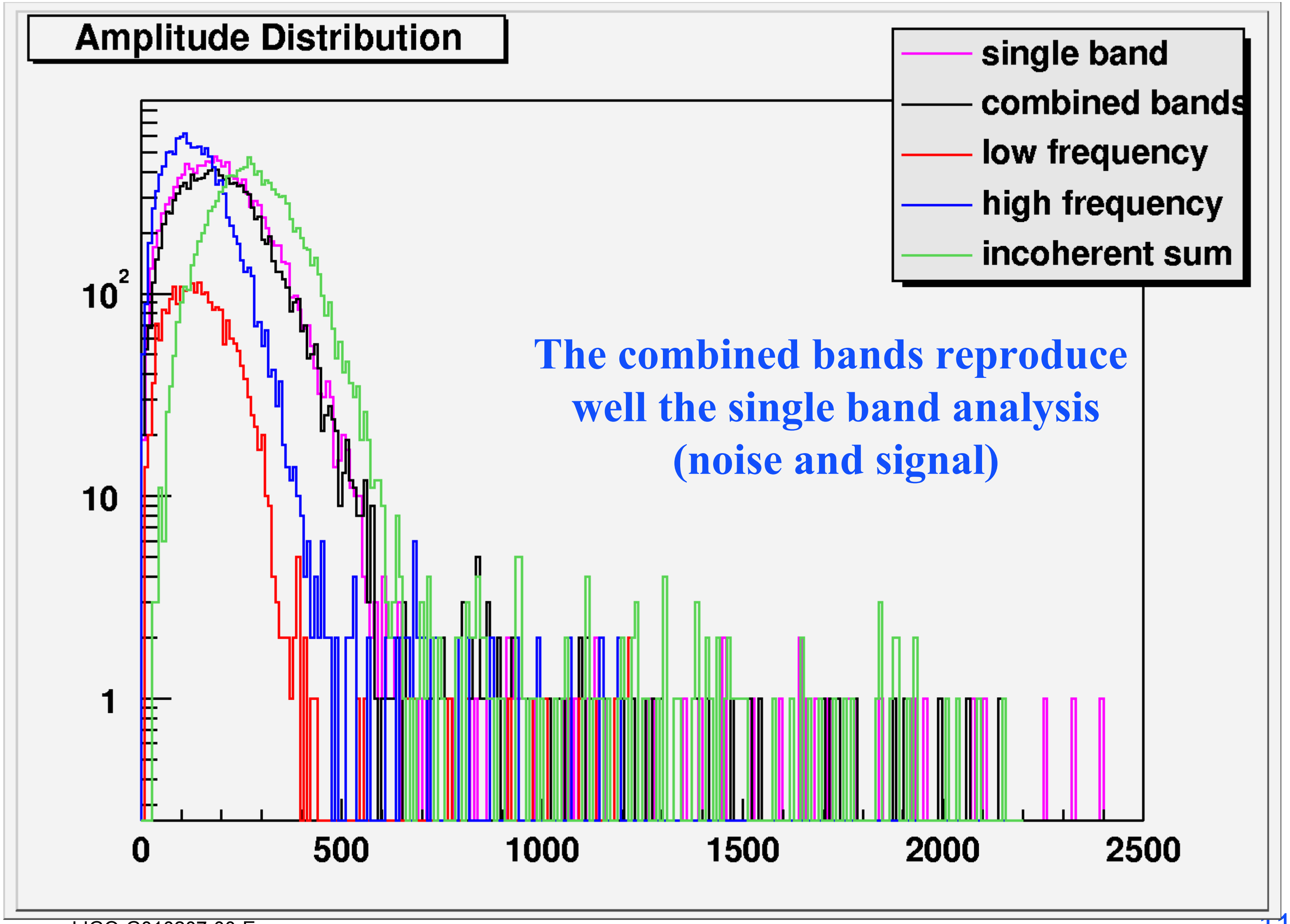
Zoom on each templates



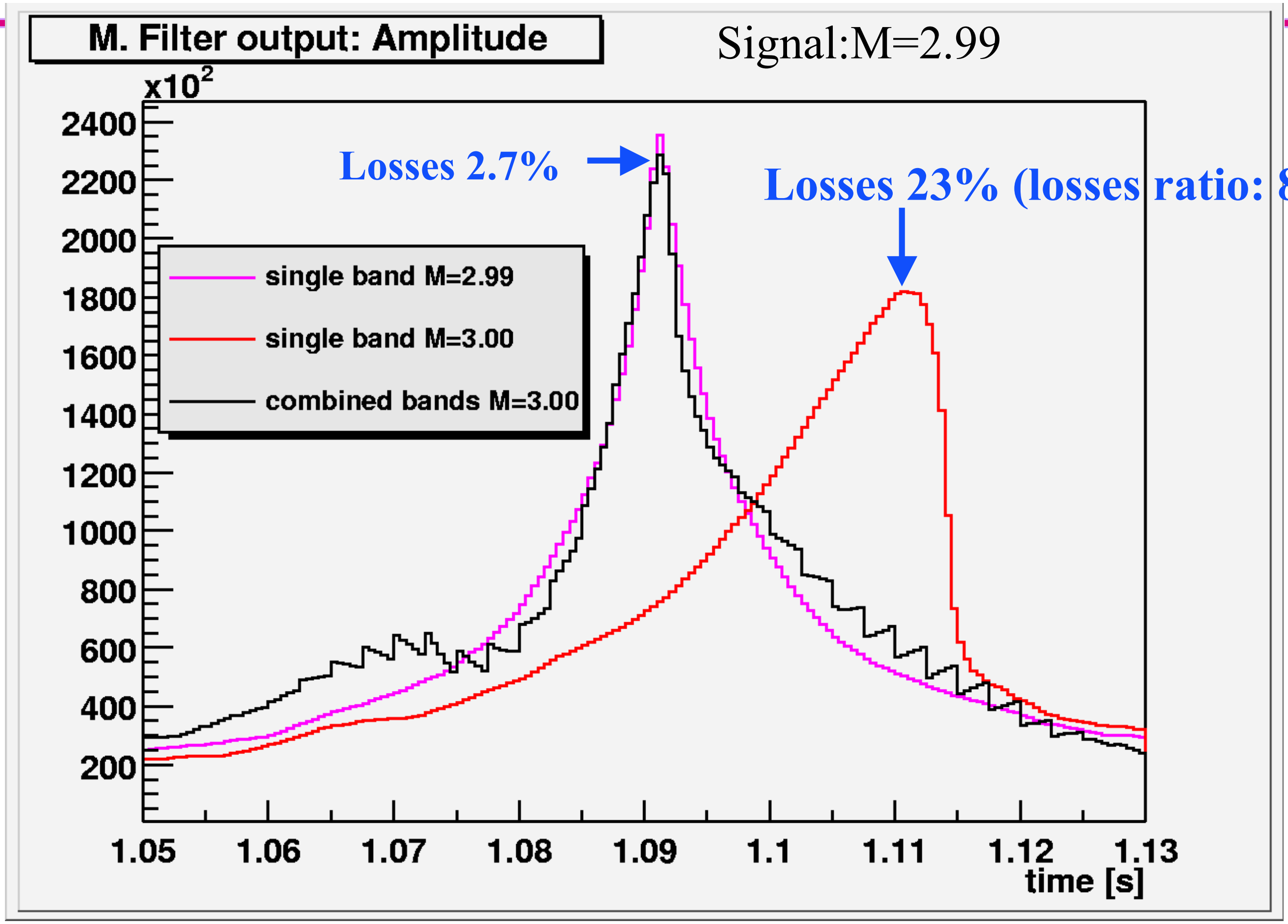
Comparison of the outputs



Comparison of the noises



LIGO Signal and Template mismatched



The parameter space is 8 time larger,

The templates are 5 times smaller

⇒reduction of ~10 for CPU, 40 for template storage

Summary

- The Multi Band Template Analysis has many advantages
  - » No SNR change
  - » Reduce the computing requirements
  - » Work on small FFT (fit in the CPU cache, use single precision)
  - » Build-in hierarchical approach without compromise on SNR
  - » Build-in consistency tests

- More study in progress
  - » Implementation problems? Is the gain as good as expected?
    - $\Rightarrow$ Building a prototype code